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Prioritization of identified environmental loss factor subject to offshore structure failures based on public perception

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Abstract. Oil spill disturbs an entire ecosystem for a quite long period of time, environment impacted by this event but less attention was drawn due to lack on documentations. This paper presents a study of the past accident related to the offshore oil and gas accident that contribute to environmental loss. It intend to assess the environmental loss quantitatively. Referring to nine cases of the worst offshore accident related to structure failure in the previous years (1969-2011), the cause of failure that contribute to oil spill and environmental loss in the previous cases was identified and categorized based on the environmental loss characteristics. Finally, data collected from the past accident is used to design the questionnaire survey in order to obtain the public perception and analysis is done by using average index of non-parametric test and analytic hierarchy process for prioritization the factor of environmental loss factor. The result shows that water pollution, air pollution, marine animal and fisherman denoted as A1, A2, B1 and C1, respectively, are very important are the most affected factor. Identifying the loss of environmental loss factor is a crucial contribution to the enhancement of the calculation of COF as well as risk assessment.

1. Introduction

Offshore oil and gas production is one of the industries that are more challenging than onshore industries due to the operation involving drilling and retrieving oil under extreme pressure. Accidents on the offshore platform can be followed by the fire and explosion, human errors, mechanical failure and so on. Offshore oil rigs activities entail the hazard of a major accident with potentially severe consequences to the people, pollution of the environment, asset, and also reputation of the oil company. However, this study concentrate on the environmental loss factor resulting from oil spill of an offshore accident subject to structure failure. When oil is spilled into an aquatic environment, it can harm organisms that live on or around the water surface and those that live under water. Spilled oil can also damage parts of the food chain, including human food resources. The severity of the impact of an oil spill depends on a variety of factors, including characteristics of the oil itself. Natural conditions, such as water temperature and weather, also influence the behaviour of oil in aquatic environments. Various types of habitats have differing sensitivities to oil spills as well.

The risks arise in every aspect of our lives. As an example, we cannot expect an accident to occur even when some cars move slowly as we cross. This is because we cannot expect many possibilities that will happen without us being aware. The offshore oil and gas industry, with its complex and dynamic

nature, is not an exception. It suffers a lot of risks both internal and external that affects peoples, asset, environment and reputation. The database from Google Earth files give the information about 50 worst oil spill from drilling operations and involving the worst spill history over 10,995,000 barrels [1]. However, availability of data sources on past accidents is very limited especially related to environmental loss because there is no effort to document the environmental loss factors by structure failure specifically. If environmental loss factor due to oil spill is not documented, it is bad because important experienced gained from these occurrences may be underestimated and will not being practiced in most industries. Therefore, the identification of environmental loss factor is simplified and categorized according to the loss characteristics to ease the process of calculation COF. Moreover, the prioritization done in currently available standards usually not refer to public preference, which explained the impacts of the accident either negative or positive on the owner itself only.

This study aims to investigate the impact of offshore structure accidents on the environment from the public perspective. The objectives are drawn to achieve the aim of the study as follows: (i) to identify the environmental loss factor subject to offshore oil and gas structure failure, (ii) to categorized environmental loss factor based on the loss characteristics, and (iii) to prioritize the environmental loss factor according to public perspectives. This study involved risk assessment of offshore structure failure. Offshore accidents cases involving structure failure like leakage, wellhead blowout, drilling error and so on are selected as a case study and analyzed in terms of environmental loss factor. The scope of the study is further detailed with regard to the case of the accident which has resulted more than 1000 barrel of oil spill which considered as major accident [2]. Furthermore, this study looks at the offshore accident for the last 50 years from 1969 to 2011. However, accidents involving years before 2009 were also studied. The case of the accident is studied more widely so that more input can discussed in the study in terms of impact to the environment whether it is present or involving long-term effects. Upon identifying the environmental loss subject to structure failure, the environmental loss factor will be categorized according to the loss characteristic for the next analysis purpose using statistical analysis and AHP for prioritization the environmental loss factor.

2. Literature review

The term risk is used in many ways and is given different definitions depending on the field and context. Common to most definitions of risk is uncertainty and undesirable outcomes. For Health and Safety, risk is defined as a potential for realization of unwanted event, or during work activities or by the products and services created by work activities, negative consequence of an event [3]. In oil and gas industry, risk is the concepts of treat. In the presence of threat there is a potential threat. Risk is the product of probability of an events and consequences associated with the event. Accordingly, high consequences events occur when as much risk as frequents event during a time period of interest. Estimating the frequency with events occurs is as important to managing overall risk related to these threats to as accurately predicting the consequences.

When there has an offshore accident, there is always the possibility of harming the environment, which could end up having long term deleterious consequences on local residents. Plus, if the environment becomes polluted, whether via large oil spill or unknown leakage, this can disrupt the local food supply, as recently occurred within the Gulf [4]. The environmental effect can turn out to be costing considerable sums of money, because the clean-up and recovery cost to those affected may be an ongoing trouble for years and years into the future. Of course, it is also unwise to be the company that destroys valuable land, and the damaged reputation will result in a large number of other difficult financial calculations. Hence, the impact of oil spill accidents on the environment is the most important concern and attention in all impacts.

There are many databases reported the offshore accidents such as the National Transportation Safety Board (NTSB) which an independent investigations agency for aviation of accident and significant of the accident that happened in United States [5]. These report mostly focus on the facts of the accident example the cause of the accident, visible loss due to accident impacts, recommendation of safety and so on, hence the oil spill that gives the effect to the environment and environmental loss factor for certain

event happened could not be properly identified. In the PETRONAS Technical Standards of Pipeline Operational Risk Assessment, the risk assessment is explained in detail and also the consequence of the failure to the safety, economy, environment and reputation [6]. These standards describe the severity of the impact of a pipeline accident to the environment but unfortunately the details of each case of accident happened and the environmental loss factor of an accident is not described properly.

The occurrences of oil spill accidents will inevitably have effect on the ocean and product in quality of polluted water. Hence give impact to the marine ecosystem. Marine ecosystem comprises of various animals in term of shellfish, fish, mammals and marine worm that live in contaminated water will exposed to various degree of impact during an oil spill accident. At the same time, spilled oil pollution may block the ongoing trading activities at the surrounding environment which affect the fisherman economic income and also to the farmers. In addition, the oil spill even damaged to its plants (flora and fauna).

Analytic Hierarchy Process (AHP) method for prioritization process was used to rank the priority vectors of environmental loss factors. Hence, by all prioritization, the oil and gas industry or offshore operator can apply the mitigation measures immediately according the factor that formerly to be dealt with. This paper utilized the data that has a time difference of more than ten years from the same pipeline. The inspection was conducted by two different vendors using the same inspection tool call MFL tool. Figure 2 illustrates the schematic overview of pipeline corrosion idealization view. The features of metal loss corrosion such as defect location (e.g. orientation, relative distance, and absolute distance), number and size of the metal loss features are provided in the ILI data.

3. Methodology

A number of nine case studies consisting of the characteristics of major offshore accident related to offshore structure failure within past 50 years (1969-2011) were selected as the case study. The study is further examined by looking at offshore accidents related to structure failure and resulting in oil spill. To meet the need of the study, the oil spill must give a significant effect to the environment. The environmental loss indicators were identified through in-depth study on each selected cases and categorized the environmental loss factor based on loss characteristics. From the selected offshore accident case studies, the questionnaire survey was designed in order to obtain the public perception via links of Google Forms

3.1. Research design

The research design refers to the overall strategy used to integrate the different components in the study in a coherent and logical way. It constitutes the blueprint for the collection, measurement, and analysis of data. The first of this study is a case study. The case study is an in-depth study of a particular research problem which is by identifying the latest offshore oil and gas accident cases from 1969 to 2011. Although the data were taken in the year before 2000 but the more we studied the case of the accident, the more input that we can discussed in our study in terms of environmental loss. In correspondence with the scope of the study, the study is examined by looking at offshore accidents involving structure failure and resulting in oil spill and significant losses in terms of environment. To meet the needs of the study, the details of the accident have been recorded including the accident time and date, the location of the accident, the owner of the offshore oil and gas industry, volume of oil spill that more than 1000 barrels [2] and causes of the accident in term of structure failure. Figure 1 illustrate the methodology flow chart for a brief study.

3.2. Data collection

The major source of data which constitutes the primary source of data is collected by reading all the news, article, journal, official website and others. After identifying and collecting data on offshore accident subject to structure failure, the study continued with identifying and determining the environmental loss for each accident cases The summarized of environmental loss factor for each accident case is as follows in Table 1. Furthermore, the environmental loss factor of the offshore accident

for each statement through literature search will be determined by referring to the definition of each factor as shown in Table 2. It was then classified according to loss characteristics as shown in Figure 2.

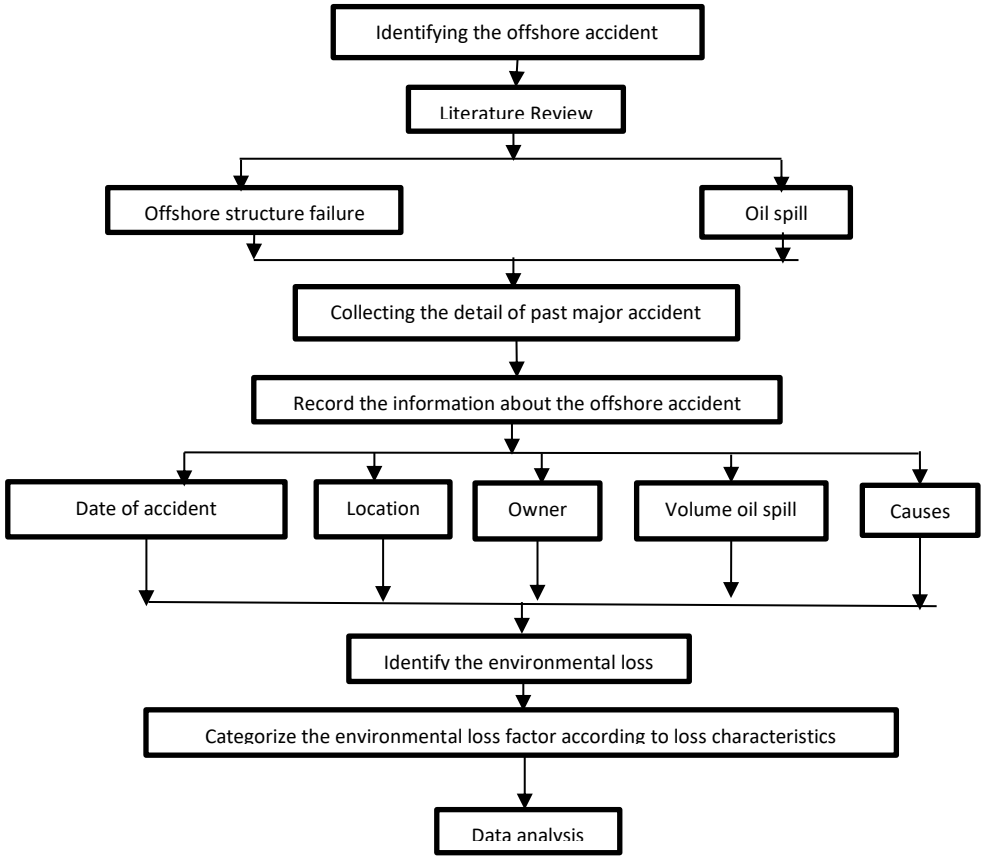

Figure 1. Research methodology flowchart.

Table 1. Summary of the environmental factors in the selected case study of major offshore accident.

Case No.	Environmental Loss												Total
	Pollution				Flora and Fauna				Public				
	Ocean	Shore	Air Pollution	Smell Pollution	Marine animal	Organisms	Birds	Plants	Fisherman	Farmers	Tourism	communities living along the	
1	✓	✓		✓	✓		✓	✓			✓		7
2		✓			✓	✓	✓	✓	✓				6
3		✓		✓	✓		✓	✓					4
4		✓			✓								2
5		✓	✓	✓	✓	✓	✓				✓	✓	6
6		✓			✓				✓	✓		✓	5
7		✓		✓	✓	✓	✓	✓	✓				3
8		✓			✓			✓		✓	✓		5
9		✓		✓	✓				✓				3
Total	1	9	1	1	9	2	5	4	3	2	3	1	

Table 2. Identified Environmental loss factor and its indicators found in the selected major offshore accidents case study.

Code	Environmental loss factor	Descriptions
A1	Water Pollution: Ocean and Shore	Ocean is oil split in Deepwater. Shore is oil spill found at shore/beach
A2	Air Pollution	Air pollution due to depleted uranium (DU) exposure
A3	Smell Pollution	The smell from petroleum
B1	Marine animal	Marine animal classifies into Shellfish, Fish, Mammals, Marine worm. Shellfish: an aquatic animal having a shell. Shellfish fall into 2 different groups. Group 1 is Crustaceans (is an animal with hard shell and several pairs of legs, which usually lives in water) like shrimp, crab or lobster. Group 2 is Mollusks (is an animal with a soft unsegmented body usually enclosed in a calcareous shell broadly) like clams, mussels, oyster, scallops, octopus, or squid. Fish: fish that live in marine environment. Mammals: marine mammals are aquatic mammals that rely on the ocean and other marine ecosystems for their existence. They include animals such as seals, whales, manatees, sea otters, dugong or dolphin. Marine worms: Any worm that lives in a marine environment is considered as marine worm.
B2	Birds	Birds that live in or near the ocean that exposed to oil spill
B3	Plants	The effect of oil spill to flora and fauna. Example: Mangroves, seagrass, underwater flora, kelp forest, surfgrass.
C1	Fisherman	One who catches fish and other animals from a body of water is losing as they can no longer catch fish caused by oil spill
C2	Farmers	The oil spill destroyed a large number of sea cucumber and seaweed farms.
C3	Tourism	It caused huge losses to the tourist as oil spill reach the beach and cannot do the leisure activities.
C4	Communities living along the coast	Oil reached the shoreline with an adverse effect on communities living along the coast.

3.3. Data analysis

In line with this methodological approach, research tools associated with quantitative approaches such as online surveys were combined to collect the data. Quantitative approach is used to quantify attitudes, opinions, behaviors, and other defined variables and also generalize results from a larger sample population. The questionnaire designed based on literature review and case studies that was conducted and answered online via links of Google Forms. The questionnaire was conducted in order to attain responses from public perception of this research. The Statistical Product and Service Solutions (SPSS, version 22.0) software programme was used to analyse the data and also to check the reliability of the survey data. The analysis was organized under themes derived from the data and the objective of the study that guided the entire investigation.

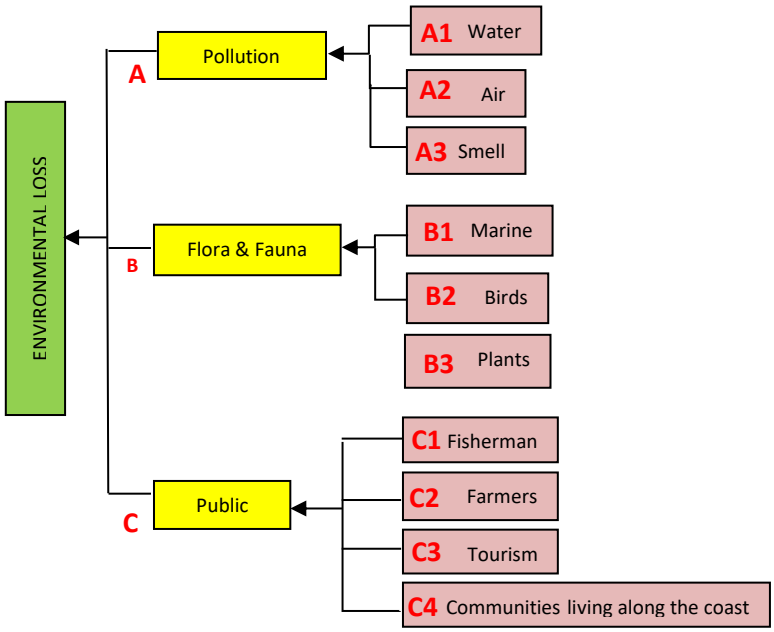

Figure 2. Environmental loss model framework.

3.4. Statistical analysis

The data obtained from the survey has to undergo reliability test that allowed to study the properties of measurement scales and the items that compose the scales. The reliability of the survey data was analyzed using the statistical analysis software, the Statistical Product and Service Solutions (SPSS) and data obtained was analyzed by average index in order to determine the relationship between the highest rank of environmental loss factor due to oil spill of an offshore accident and public perceptions. The sample size and return rate of questionnaires also determined before analysis is done. The hypothesis testing is performed to test the significant difference between samples to reconfirm the samples are not different in terms of ratings before further analysis can be executed. Therefore, the hypothesis testing involving of the Mann-Whitney test and Kruskal-Wallis test were utilized for this purpose due to the non-parametric survey data.

The data collected from the survey was tabulated according to the scale rated by the respondents summed together and averaged to obtain an index for each environmental loss factor. This index was used to rank the environmental loss factors solely based on respondent rating. The Mann-Whitney test is a non-parametric test which is suitable to be used for a Likert-scaled survey type of data, where significance of difference between two groups is to be observed. It is important to conduct this hypothesis test to test the significant differences between the samples to re-verify the sample no different in terms of ratings before the further analysis can be implemented. The Kruskal-Wallis test is another non-parametric test. The difference of this test compared to previous test is the number of groups of samples to be tested on their significance of difference. This test is applied on sample with more than two different non-independent parameters. AHP methods were implemented to prioritize the factors and then the ranking of the factors was obtained by rearranged the factors' weight in a descending manner (highest weight ranked first and vice versa).

4. Discussion

In the beginning of study, a reliability test was carried out on the perceived task values scale comprising 9 items. The reliability analysis was done in order to obtain the internal consistency so that it achieves at least 0.70 of the Cronbach's alpha reliability coefficient, and the internal consistency is at the minimum acceptable. The Cronbach's alpha of this questionnaire is 0.944, which is excellent consistency. The questionnaire has been shared to two type of media social. The questionnaire has been

shared to the groups that related to the oil and gas Industry that have more than 22000 people but unfortunately only one is responded. On the other hand, the questionnaire also has been shared in the WhatsApp group that consisting of 264 members with 49 of people responded. Hence, the total respondent between two types of media social is 50 respondents with return rate of 18.66%. The return rate may inadequate for reporting purposes and analysis; the responses are recorded to gain the differences of perspective between types of respondent.

Ten different environmental loss factor which may be faced in the oil and gas industry as an environmental problem if an offshore structure failure occurred. The respondent was asked to rank the level of important of these factor and they will mark 5 if they think it is very important, 4 for important, 3 for moderately important, 2 for slightly important and 1 if they think it is not important. The overall result was mostly favour of the high importance to the environment is about the water pollution, A1 as it came out the survey with high rank among the other factor with 4.70. However, the lowest rank with lowest mean value of 4.14 indicate the farmers. The respondents of this survey all agreed that factors of water pollution, A1, air pollution, A2, marine animal, B12, and fisherman, C1 are very important with scale of 5 affect the environmental loss prior to offshore accident related to offshore structure failure.

The questionnaire design covers the various type of respondent that involve customer, employee and public. Therefore, hypothesis testing needs to be executed in order to avoid significant differences between ratings of different type of respondent. It is hypothesized that there is no significant difference of environmental factors ratings between customer, employee and public. The significance levels for all factors have to be more than 0.05 so that the null hypothesis cannot be rejected. If so, it shows there is a 5% chance that the results falling in the critical region have occurred by chance. In conclusion, all tests are aimed for not rejecting the null hypothesis so that the ratings for environment loss factors is not significantly different. Non parametric Kruskal-Wallis is done because the hypothesis testing is applied to three different non-independent parameter of customer, employee and public. It shows that the null hypothesis is not rejected for all factors in different type of respondent. Similarly, the null hypothesis of Mann-Whitney H test for awareness of oil and gas accident is not rejected as the significance levels for all factors are above 0.050.

Table 3. Priority vector for each factor.

Factor	Sub-Factor	Average	Std. Dev.	%CV	Rank
A	A1	0.38032	0.0702	18.47	1
	A2	0.34089	0.0659	19.34	3
	A3	0.27879	0.0850	30.49	7
B	B1	0.37908	0.0772	20.36	2
	B2	0.29435	0.0780	26.48	5
	B3	0.32656	0.0553	16.92	4
C	C1	0.28062	0.0644	22.95	6
	C2	0.22138	0.0594	26.85	10
	C3	0.23539	0.0662	28.12	9
	C4	0.26261	0.0733	27.91	8

5. Conclusion

As a result of research obtained from news, articles, journal and websites, there are reports or information available related to offshore accident due to offshore structure failure. The accident must have a significant effect to the environmental loss. From an in-depth study of a particular research problem, the environmental loss factor was obtained and recorded with appropriate table containing of time and date accident, location, owner of oil and gas industry, and volume of oil spill. This study can be used as a reference to certain parties such as oil and gas industries to study the environmental loss

factor subject to offshore structure failure if required in the future as there is no proper record of the accident currently.

Then from the identified factors, it was categorized according to its similarities in characteristics. For example, oil spill that spillage on shore or ocean is categorized on one characteristic which is water pollution. Next, Animal and plants that affected by the oil spill is categorized under theme called flora and fauna. However, animal is divided again into two since two type of different ecosystem is affected which is marine animal and birds. Lastly is public categorization means that oil spill that affected fisherman, farmers, tourism and communities living along the coast prior to offshore accident related to structure failure. This categorization is significant for environmental loss evaluation later. It will ease the oil and gas industries to calculate the consequence of failure (COF) in order to reduce the risk.

The results obtained as the whole environmental loss shows that water pollution, A1, air pollution, A2, marine animal, B1, and fisherman, C1 are very important with scale of 5 compared to others using the average index method. However, after it categorized and the prioritization is made, it has the same result for both methods. The water pollution, air pollution, marine animal and fisherman is highest priority for each factor in global based on public perspectives. The higher of the weightage value shows that the factor is more important and rank as first priority. Thus, identifying the priority of which factor to be taken care of based on public perception are suggested to the offshore operator or oil and gas industry in the post-accident responses of oil spill subject to structure failure for risk assessment. Hence, the impact environmental loss can be reduced.

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